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Indian Standard

CODE OF PRACTICE FOR LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART VIII PRECIOUS METALS

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Indian Standard

CODE OF PRACTICE FOR LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART VIII PRECIOUS METALS

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Indian Standard

CODE OF PRACTICE FOR LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART VIII PRECIOUS METALS

0. FOREWORD

0.1 This Indian Standard (Part VIII) was adopted by the Indian Standards Institution on 31 July 1974, after the draft finalized by the Chemical Engineering Sectional Committee had been approved by the Mechanical Engineering Division Council.

0.2 This standard is being issued in many parts, the precious metal lining of vessels and equipment is covered in this part, the other types of linings are covered in the remaining parts of this standard.

0.3 This part offers guidance to manufacturers and users of vessels lined with silver, platinum and its alloys and other precious metals, such as gold, palladium, rhodium, iridium and ruthenium, which are rather more limited in their application.

0.4 Silver linings are applied as either loose or bonded linings to mild steel or copper vessels. Platinum is normally used as a loose lining.

0.5 Silver and platinum are also used frequently in the solid form and occasionally in the clad form for fabricating process plant. This part does not cover this type of equipment.

0.6 It is desirable that early consultation and exchange of information should take place between all parties concerned in the design, manufacture and use of vessels and equipment which are intended to have a precious metal lining. Attention should be paid to all aspects of the design of the vessel and the lining to ensure continuity of the lining on all surfaces to be in contact with the product.

0.6.1 If a lining is to be fitted to an existing vessel already in service, special attention should be given to the condition of the existing surface.

0.6.2 An accurate detailed drawing, to scale, should be made available to all parties concerned. Appendix A gives details of information to be exchanged at this stage.

0.7 In the preparation of this standard considerable assistance has been derived from BS CP 3003 : Part 8 : 1970 'Lining of vessels and equipment for chemical processes — Part 8 Precious metals', issued by the British Standards Institution.

0.8 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part VIII) lays down recommendations on the design of vessels for precious metal linings, method of application of linings, inspection and testing.

2. MATERIALS

2.1 Silver

2.1.1 Silver suitable for lining should have the following composition:

a) Silver not less than 99·97 percent; or

b) Silver plus copper not less than 99·99 percent, where the silver content is not less than 99·97 percent.

These materials have a high resistance to a range of corrosive agents, in particular, organic fluids containing both halogens and phosphorus.

For certain applications, silver of purity higher than 99·99 percent may be required.

2.1.2 Silver has a high resistance to most dilute mineral acids, either hot or cold. It is resistant to sulphuric acid except when the concentration is above 80 percent and the acid is hot. Under certain conditions it can also resist hydrochloric acid. Hydrochloric acid does not attack silver appreciably and the metal shows effective resistance to phosphoric acid. However, it is readily attacked by nitric acid or hydrobromic acid at all concentrations. The resistance to hot or cold organic acids is extremely good.

2.1.3 Alkaline solutions have no effect on silver even at high temperatures. Silver has a satisfactory resistance to fused alkalis in the absence of oxidizing agents, including moisture. Silver is rapidly attacked

*Rules for rounding off numerical values (*revised*).

by cyanides but is nevertheless resistant to a great number of salt solutions. Silver does not oxidize in air but on normal exposure it quickly forms a tarnish film of silver sulphide.

2.2 Silver Alloys — For certain applications, greater hardness and strength are required than is obtainable with pure silver. For these applications alloying with up to 2 percent copper is normally employed, but some loss in corrosion resistance may result.

2.3 Platinum

2.3.1 Platinum suitable for lining should have the following composition:

a) Platinum not less than 99·8 percent; or

b) Platinum plus other platinum group metals, not less than 99·99 percent, where the platinum content is not less than 99·8 percent.

2.3.2 Platinum is attacked by aqua regia and by any other combination in which hydrochloric acid or chlorine is present in oxidizing conditions, but apart from slight action by concentrated sulphuric acid at high temperatures it is virtually unaffected by other acids.

2.3.3 It is very resistant to alkalis, oxides and salts but may be attacked by fused caustic alkalis and by certain cyanides and peroxides at high temperatures.

2.3.4 Organic reagents generally have little effect, except that catalytic activity and the presence of hydrocarbon vapours at high temperatures may lead to surface etching. Platinum will alloy with molten gold, silver, lead, nearly all other base metals and any elemental arsenic, phosphorus, boron and silicon, so that reducible compounds of these elements should not be heated in contact with platinum under reducing conditions.

2.4 Platinum Alloys

2.4.1 For certain applications, greater hardness and strength are required than is obtainable with pure platinum and for these applications, alloying with gold or other platinum group metals is normally employed, since, besides improving the mechanical properties they normally enhance corrosion resistance.

2.4.2 The principal platinum alloys used for linings are the platinum-rhodium alloys containing 5, 10, 20 percent rhodium; alloys containing 5, 10, 20 percent rhodium; alloys containing 30 percent and 40 percent may be used but are not so easy to fabricate because of their poor ductility. Alloys containing more than 40 percent rhodium have little ductility and are difficult to fabricate.

2.4.2.1 The general corrosion resistance of platinum-rhodium alloys is similar to that of platinum, although their stability at high temperatures and excellent creep resistance even above 1 000°C are factors that determine their use in high temperature applications.

2.4.3 Platinum-iridium alloys are more resistant to attack by aqua regia and the halogens than is pure platinum.

2.5 Other Platinum Group Metals — This group includes palladium, rhodium, iridium and ruthenium and their alloys; they may be used for fabricating loose liners. Palladium is ductile and is readily fabricated. Rhodium, iridium and ruthenium are much less ductile and very difficult to fabricate. Palladium is attacked by halogens, nitric acid, aqua regia, hydrobromic acid, or hot sulphuric, selenic or perchloric acids, and is highly permeable to hydrogen. Palladium, rhodium and iridium are not attacked by oxidizing alkaline solutions. Rhodium and iridium are resistant to attack by mineral acids and halogens, but are slightly attacked by fused alkalis. Ruthenium is particularly resistant to aqua regia, mercury and molten lead.

2.6 Gold — Gold is rarely used as a loose lining but is occasionally used as an electro-deposited lining.

2.6.1 Gold does not form an oxide or a sulphide tarnish. Individually the mineral acids have no effect upon gold, although the presence of nascent chlorine in hydrochloric acid will cause attack. Aqua regia will rapidly dissolve gold as will any mixture capable of producing nascent halogens.

2.6.2 Concentrated sulphuric acid containing strong oxidizing agents slowly attacks gold. In the presence of air or other oxidizing agents, alkali cyanides will readily dissolve gold but it is unaffected by common alkalis. Organic materials generally have no effect upon gold.

3. DESIGN OF VESSELS AND EQUIPMENT FOR LINING

3.1 Design Considerations

3.1.1 *General* — Vessels to be lined should have surfaces that are smooth and continuous in order to ensure that the lining can bed down with good contact against the inner walls of the vessel over the whole area. Where the vessel cannot be made in one piece it should be welded construction using butt welded joints.

3.1.1.1 Wherever possible the shape should be cylindrical with end either flat, conical or dished and with as large a radius as possible in any corners which occur. Irregular shapes may be lined but will be more difficult and costly.

3.1.1.2 The vessel should be fabricated and tested in accordance with recognized standards of good design and practice to suit the operating conditions. For guidance on these requirements reference may be made to IS: 803-1962* and IS: 2825-1969†. Whether the lining is attached to the wall or not, it is not generally considered in the calculation to determine the strength of the vessel. No internal corrosion allowance need be made in assessing the thickness of the outer shell. It may be appropriate to incorporate a corrosion allowance on the outer surface of the vessel, for example, where spillage may occur or where the vessel is provided with a heating or cooling jacket. Where thermal stresses are likely to be set up by the attachment of lining then the necessary allowances should be made in the design of the vessel.

3.1.1.3 The drawing of the vessel should give full details of construction, including any holes through the shell that are required for test purposes, and the method of lining should be shown. These test holes should be drilled through the shell before the lining is applied. Loose linings in precious metals are normally prefabricated outside the vessel. Due allowance should be made in the design to ensure that access to the vessel allows the lining to be accurately and easily placed in position.

3.1.1.4 Should the wall of the vessel required to have good heat transfer properties, this can be achieved by using bonded or electro-deposited linings.

3.1.1.5 The design may require suitable relief or drainage holes (*see* **4.2.4**).

3.1.2 *Internal Fitting* — Where internal fittings are required, such as support rings, brackets and coil support, these may be fabricated from solid precious metal of the same specification as the lining.

3.1.2.1 Where these are fixed to the vessel wall and are required to carry load under operating conditions it may not be economical or practical to make the fitting from solid precious metal, since these metals do not have particularly strong mechanical properties. In this case the fitting is lined after being fixed in position and the lining welded to the main lining.

3.1.2.2 Because of the difficulty in lining internal fittings it is advisable to arrange for these to be mounted on flanged covers or on the base of the vessel, sited on a suitably prepared location.

3.1.3 *External Fittings* — Special care should be taken in designing the fittings on a vessel which break through the shell, such as manholes,

*Code of practice for design, fabrication and erection of vertical mild steel cylindrical welded oil storage tanks.

†Code for unfired pressure vessels.

branches, sight glasses and agitator glands. The lining should cover all surfaces exposed to the corrosive media.

3.1.4 *Flanged Openings*

3.1.4.1 *General* — Where loose or bonded linings finish at a flanged opening they should extend part way across the flange joint face so that the diameter of the circle formed by the edge of the lining just covers the flange spigot and is adequate to ensure a satisfactory seal. The orifice of the flange should have a radius on its edge of at least 1·5 mm.

It is sometimes possible to flange over the lining tube to cover the required area on the flanged joint face, without significantly thinning the lining material. The amount of thinning acceptable should be agreed between the fabricator and the client. This method is shown in Fig. 1.

The usual method of lining flanges is shown in Fig. 2. The lining tube is flanged over in the shape of a wide angled funnel; at this stage the lining is not made to lie flat on the flange face. (With silver linings that have been tinned, prior to bonding, the tinned coating should be removed from the area extending 12 mm) away from the edge to be welded. This may be done by scraping away the majority of the coating and dissolving the remainder away with 50 percent nitric acid. Nitric acid should not be allowed to run between the lining and the vessel wall.

An annulus is shaped so that its inner orifice fits nearly round and just on the outer edge of the flanged-over lining. This annulus is first tack welded and then fully welded into position.

A wedge shaped anvil is then placed on the flange beneath the lining and the weld is hammered flat. The anvil is then removed and the hammered weld is torch annealed (flanged of silver linings that are to be bonded should be retinned at this stage). The lining is then compl ely flanged over to match the contour of the flange face.

With loose linings it is usual to attach the edge of the lining to the flange to prevent the lining lifting each time the joint is opened. The edge of silver linings may be brazed or soldered, the edges of platinum metal linings are brazed.

Where it is particularly important for a lined flange to make a pressure leak-tight joint alternative methods exist for silver and platinum group metals linings.

3.1.4.2 *Silver* — To make pressure leak-tight joints with silver lined flanges, their surfaces should be machined. The lining thickness over the flange face should be increased to provide sufficient metal to allow for machining. This thickening is achieved by making a shaped annulus

to fit over the flange face, from thick silver sheet, and joining this annulus to the lining. The annulus is joined to the lining by welding with the method shown in Fig. 3.

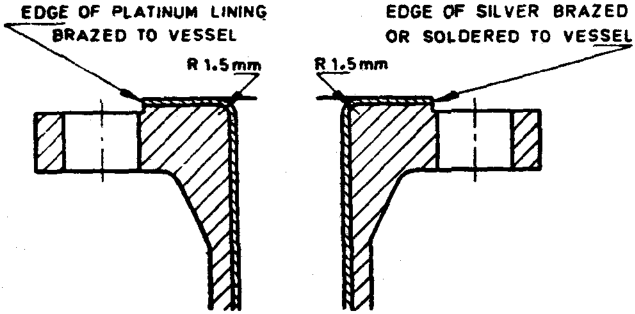

Fig. 1 Typical Method for Lining of Flange Face, Small Diameter

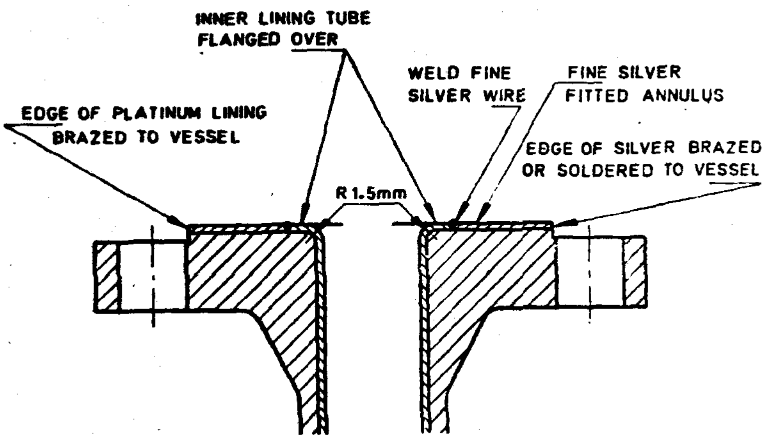

Fig. 2 Typical Method for Lining of Flange Face, Large Diameter

3.1.4.3 *Platinum group metals* — Where pressure leak-tight joints are required with these linings, tongued and grooved flanges should be used; machining of platinum group metal flange face linings is economically impracticable.

The flange lining is made by the usual method of welding an annulus on to the tube lining as described in **3.1.4.1** and shown in Fig. 2. The flange linning is shaped to match the tongue and groove

contours after the annulus is joined to the tube lining. The grooved flange should be machined to accommodate thickness of the metal lining on both tongue and groove, and the corners of both tongue and groove should be radiused. The method of lining is shown in Fig. 4.

A joint ring is often inserted between the lined tongue and groove to ensure that the lined flanges can easily be separated after they have been clamped together. The joint ring, usually about 0·25 mm thick is made of a platinum group metal, different from that of the lining; iridium or palladium are often used for this purpose.

3.2 Materials for Vessels — Carbon steels are the most commonly used group of materials from which a vessel should be constructed if it is to be subsequently fitted with a lining. Copper and nickel alloys are also used. The quality and thickness of the material chosen should be such that the subsequent fitting of the lining in position will not adversely affect the structure of the vessel.

3.2.1 The surfaces to be lined should be smooth and clean and free from scale. Iron grit blasting is recommended as a suitable finish for carbon steel vessels. Copper and nickel alloys should be chemically cleaned.

3.2.2 Surfaces to be lined by electro-deposition should be free from porosity.

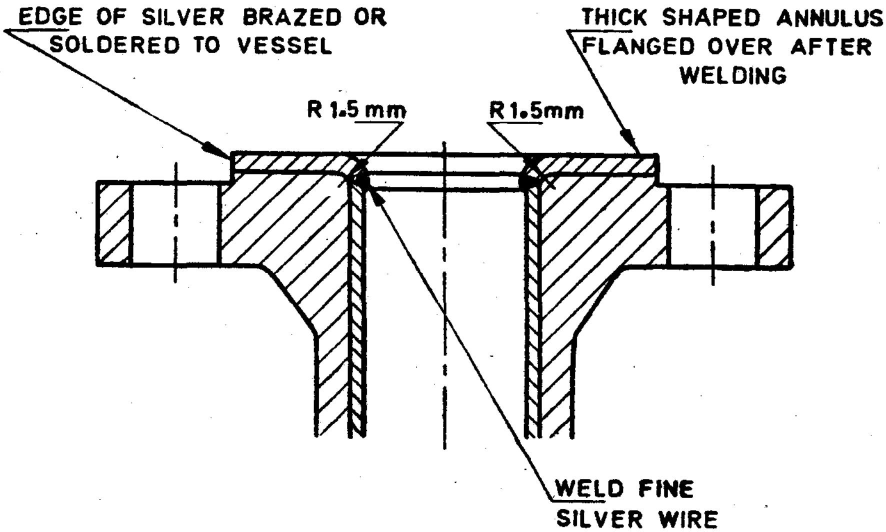

FIG. 3 TYPICAL METHOD FOR SILVER LINING OF FLANGE FACE WHERE MACHINING IS REQUIRED

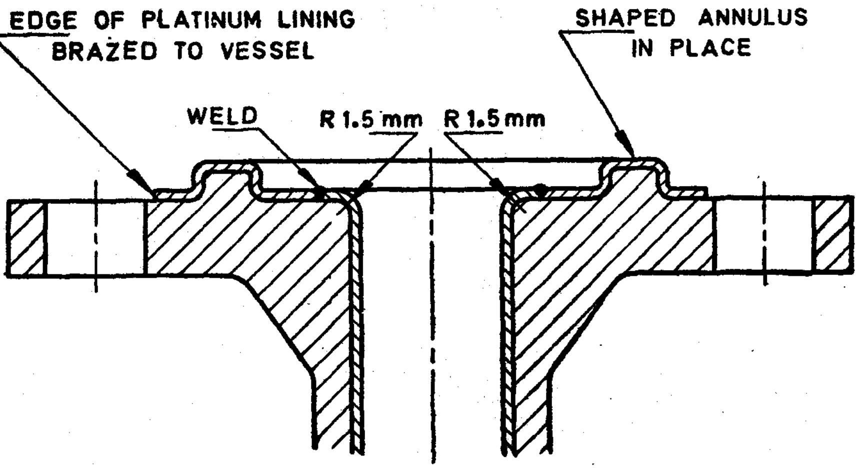

FIG. 4 TYPICAL METHOD FOR LINING OF TONGUE AND GROOVE FLANGE FACE WITH PLATINUM GROUP METALS

4. DESIGN OF LININGS

4.1 General Factors Affecting Design — The design of lining used will depend upon a number of considerations, including:

a) range of operating temperature,
b) range of operating pressure,
c) corrosive media present,
d) erosion,
e) accessibility of inner surface for application of lining,
f) whether lined during original manufacture or after installation,
g) condition of vessel if already in service, and
h) cost.

4.2 Loose Linings

4.2.1 Loose linings are close fitting linings, prefabricated to shape outside the vessel and pressed or expanded into the correct position inside the vessel.

4.2.2 Loose linings should not be used for vacuum working conditions because they may collapse inwards from the vessel wall.

4.2.2.1 Where loose linings are used on vessels containing gases under very high pressures, gas may diffuse through the lining and collect behind it. The gas trapped under pressure may cause the lining to collapse when the pressure inside the vessel is released. A small hole or holes in the shell should be provided to allow adequate relief of pressure behind the lining. Such holes should also be provided if there is a possibility of moisture becoming trapped behind the lining of a vessel which is used above 100°C in service.

4.2.3 Holes in the shell are valuable under some circumstances other than for the release of gas pressure behind the lining as they can be used to provide early warning of a leak in the lining.

4.2.3.1 Such tell-tale holes are particularly useful for a pressure vessel operating at temperatures above the atmospheric boiling point of their contents or which are handling a solution of gases or low boiling substances. The volume of gas or vapour produced by flashing at even a small leak in the lining can be detected, and as a gas readily finds its way behind the lining to the hole in the shell a leak can normally be detected before serious damage to the shell has occurred. For critical duties it is possible to connect the tell-tale holes to a manifold connected to a sensitive detection device which may be used to provide an alarm.

4.2.3.2 Tell-tale holes are less useful for vessels operating at lower pressures and temperatures such that the contents escaping through a leak in the lining remain liquid. Under such conditions the presence of a leak may not be detected until serious damage has been done to the shell.

4.2.4 If tell-tale holes or holes in the shell to allow relief of gas pressure are used this should be taken into account in the design of the shell. The size and spacing of the holes should also be considered. Small holes are easily blocked and this can lead to a false sense of security, whereas large holes weaken the shell of the vessel (particularly of a small vessel) and may lead to a failure of that part of the lining which is unsupported. Holes of diameter 1·5 to 6 mm are suitable for most purposes and should be deburred just sufficiently to remove the sharp edge. A spacing of about 900 mm between holes is recommended.

4.2.4.1 Where the inner surface of the steel shell is required to have a smooth finish it may be desirable to connect the tell-tale holes to a pattern of escape paths on the inside wall of the vessel, but this is not usually necessary with other surface finishes.

4.3 Bonded Linings

4.3.1 *Soldered Bonded Lining*

4.3.1.1 Of the precious metals used for linings, only silver can be bonded by this technique. Soldered bonded linings in gold, platinum and

its alloys are impracticable because of the ease with which these metals form low melting alloys with the solder.

4.3.1.2 Soldered bonded silver linings are suitable where the design requires the composite wall to have a high rate of heat transmission or where it is required to work under vacuum conditions. It is not generally possible to fit bonded linings to thick walled pressure vessels.

4.3.2 *Electro-deposited Linings* — Electro-deposition of silver or gold in a fabricated base metal vessel or structure is an entirely satisfactory method of lining, provided that due attention is paid to the design of the item to be electroplated, particularly for vessels with surfaces or shapes difficult to line by other methods, as in the case of perforated centrifuge baskets or for the interior surfaces of valves and other equipment.

4.4 Thickness of Lining

4.4.1 *Loose Linings* — Silver is normally bonded but loose linings are employed and are normally 0·75 mm thick, though they can be as thin as 0·65 mm or as thick as 2·5 mm on simple shapes.

4.4.1.1 Platinum and its alloys, gold and other precious metals are usually used at thicknesses of 0·23 to 1·0 mm. Where the design required and the economics allows, thicknesses up to 2·5 mm are practicable.

4.4.2 *Bonded Linings*

4.4.2.1 *Soldered bonded linings* — Soldered bonded silver linings are normally 0·75 mm thick, though they can be as thin as 0·65 mm or as thick as 2·5 mm on simple shapes. On flange faces the thickness is usually 3 mm if subsequent machining is intended.

4.4.2.2 *Electro-deposited linings of silver and gold* — The thickness used for linings, which are usually in excess of 0·25 mm are more than sufficient to prevent channelling through the pores to the base metal.

Deposits at this thickness are invariably produced with rough surfaces and need to be machined if a smooth surface is required. The feasibility of machining the surface should be investigated and an allowance in terms of 0·1 mm machining thickness should be made at the design stage.

5. METHOD OF LINING

5.1 General Considerations

5.1.1 The three practical methods for lining equipment with precious metals are:

a) loose lining,

b) soldered bonded lining, and

c) electro-deposited lining.

Loose lining is feasible for all precious metal lining materials; soldered bonded lining is confined to silver; electro-deposited lining is used for silver and occasionally gold.

5.1.2 Soldered bonded and loose lining are produced from welded sheet or solid drawn tube. TIG welding is the usual process employed. If welding wire is used it should be of the same composition as the lining material, with less than 0·01 percent impurities. Before welding, all contact surfaces and the welding wire should be cleaned and degreased. The linings are prefabricated outside the vessel to facilitate the salvage of scrap precious metal produced in their construction and to allow all welds to be inspected before the lining is fitted.

5.1.3 Electro-deposited linings can be laid down only on electrically conducting surfaces which require pre-treatment techniques to ensure they are chemically clean. The electro-deposit can be confined to significant areas by use of a suitable masking medium.

5.1.4 The surface of the vessel to be lined should be smooth and free from sudden changes in contour, and any blemishes should be made good by welding and grinding. The vessel should be tested for leaks before lining.

5.2 Loose Lining — A loose lining is prefabricated outside the vessel as a close fit to the interior contour, slid into the vessel and pressed or expanded into the correct position. Where the prefabricated lining cannot be directly placed in position, as for example where the lining has to accommodate outlets from the vessel, the lining can be partially collapsed, placed inside the vessel and then expanded or hammered into place. Most precious metal linings are sufficiently ductile not to suffer damage due to slight distortion during assembly.

5.3 Bonded Lining

5.3.1 *Soldered Bonding Lining* — A soldered bonded lining is usually made by first tinning the correctly shaped prefabricated lining on its outside surface with a lead free solder. A quantity of solder is then placed in the vessel and the vessel heated to melt the solder. The lining is then slid into the vessel and handworked into position using wood formers while the solder is held above its liquidus temperatures; the excess solder is squeezed out from between the lining and the vessel wall.

5.3.2 *Electro-deposited Lining* — To produce homogeneous impermeable electro-deposits free from porosity, it is necessary to have exact control of the electro-chemical conditions.

5.3.2.1 The pre-treatment conditions should be selected and arranged in the correct sequence so that the surface to be lined is chemically clean when immersed in the electrolyte. Electrical connections made to the vessel should be capable of carrying the necessary current. Though the whole vessel is usually immersed in the electrolyte, the area covered by the lining can be restricted using a suitable masking medium.

5.3.2.2 The edge of the lining is preferably not made to coincide with corners or edges of the vessel, to avoid the risk of the electro-deposit lifting away from the base metal at these points.

6. INSPECTION, TESTING, MAINTENANCE AND REPAIR

6.1 Inspection

6.1.1 Quality control of the material and fabricating procedures for loose lined, bonded and electro-deposited equipment is very important since failure in service may cause irreparable harm.

6.1.1.1 Inspection should cover the fabrication of the vessel or equipment to be lined, the material to be used, the lining procedure throughout fabrication and the lining after completion.

6.1.2 Quality control procedures should include the following:

a) The manufacture of the vessel should be to the appropriate specification and, where applicable, a pressure test should have been carried out unless special dispensation has been obtained.

b) The internal surface of the vessel should be thoroughly clean and free from scale or foreign matter, and all surfaces to be lined should be smooth.

c) All materials used for the lining should be to the agreed specification.

6.2 Welders' Qualification Tests — Qualification tests are necessary for each of the welders employed on the various welding procedures involved in the construction of the vessel.

6.2.1 Where the outer vessel is built to a specification, for example, IS : 2825-1969* the welders' qualification tests should be in accordance with that specification.

6.2.2 Welders' qualification tests for precious metal linings will not normally be required, but if required, they should be clearly defined and subject to agreement.

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*Code for unfired pressure vessels.

6.3 Testing of Vessels

6.3.1 *General* — This code covers a variety of types of vessels which may be subjected in service to a wide range of conditions. The tests described in **6.3.2** to **6.3.4** reflect this variety of circumstances, and it is not necessarily appropriate that all the tests be applied to a particular vessel. The tests are basically of two types, those intended to prove the integrity of the vessel as a whole, and those intended to show that the lining is free from leaks. The order in which the tests are to be done should be considered carefully, both from safety aspects and because some tests may interfere with others; for example, water trapped in small leaks in a lining following a hydraulic pressure test may prevent the leaks being found in a sensitive leak test.

6.3.1.1 In vessels operating at temperatures above 100°C it is essential that water is not trapped between the lining and the shell, and this is most likely to occur during testing operations. Where tests holes are drilled through the vessel walls they should be left as tell-tale holes to show any leak in service. They will then serve as vents to release any vapour pressure behind the sections of lining during operation should there be any water or other volatile liquid included as a result of testing or in the event of a leak.

6.3.2 *Pressure Test*

6.3.2.1 *General* — Pressure tests can serve to purposes; to prove that the shell of the vessel is satisfactory for the intended service, and to prove the integrity of the lining under working conditions. In some cases there are advantages in using separate test at different times for these purposes. The shell should be tested hydraulically to the test pressure laid down in the specification to which it is made, but it may be convenient to carry out this test before work on the lining is complete, or even before it is begun, and to prove the lining by a pneumatic or hydraulic test at a lower pressure (at least the working pressure) when the vessel is complete. Appropriate precautions should be taken if a pneumatic test is used, and such a test should be done only if fabrication operations done after the main pressure test are such that they do not impair the integrity of the shell. The use of a pneumatic test has the advantage that sensitive leak detection techniques can be used subsequently.

6.3.2.2 *Testing of loose lined vessels* — The loose lined vessel should be pressure tested when complete after test for continuity of the lining. Where a prior hydraulic test to the normal test pressure has been done this test may be to a lower pressure, at least the working pressure, and may be a pneumatic test.

6.3.3 *Tests for Continuity of the Lining*

6.3.3.1 *Dye penetrant test* — Welds in the lining should be examined by a dye penetrant technique, and any cracks or porosity repaired before further testing.

The dye penetrant test may be omitted if a sensitive leak detection test such as that described in **6.3.3.3** is to be applied.

6.3.3.2 *Air test* — The lining should first be tested by introducing a pneumatic pressure between the shell and lining and the welds swabbed with soap and water. A pressure of about 35 kPa is adequate to detect any leaks and these will show up as a cluster of bubbles. High pressure is not an indication of more stringent testing as the air from pinholes may jet through the soapy water and produce few or no bubbles and hence not be detected. There is also a danger of lifting and bulging the lining with pressures above 50 kPa.

Air may be introduced by one of two methods, either:

a) drilled and tapped holes through the vessel, or

b) drilled and tapped holes through the lining plates.

Another method requires a rubber cup of suitable size and similar in shape to a stethoscope which is attached by a rubber tube to a small vacuum pump. The rim of the cup is moistened with soap solution, glycerine or other viscous liquid so that a seal is formed and the cup moved over the surface of the welded seams. Where the weld is sound the cup will either collapse under suction or draw air through the sealing liquid, and leaks are found where there is no collapse or drawing in of air. This method will be successful only when the weld beads are kept flush with the adjoining metal.

A further alternative is to use a vacuum box fitted with a glass top and sealed to the vessel by a soft rubber gasket. The surface of the vessel is moistened with a soap solution and the box placed over the area to be tested, the presence of a leak being shown by formation of bubbles visible through the glass top of the vacuum box. It is not necessary to introduce air pressure between shell and lining, although the sensitivity is increased if this is done.

A more sensitive test is obtained by introducing air into the vessel itself and checking for leakage at vent holes in the shell. Leakage can be detected by use of soap solutions, ultrasonic detectors or by connecting manometers or other pressure indicating devices to the vent holes. This technique allows the use of higher air pressures than can be safely introduced between the shell and lining, but can show only the approximate location of a leak, which should be located accurately by, for example, dye penetrant examination of the inner surface of the vessel or one of the sensitive leak detection methods described in **6.3.3.3**.

6.3.3.3 *Sensitive leak detection techniques* — A number of techniques can be used in which the vessel or the space between shell and lining is pressurized with air containing a small amount of an 'impurity', the

active agent; leaks are detected by devices which are very sensitive to traces of active agent. The techniques are extremely sensitive, and should be used only when it is important to ensure that the integrity of the lining is greater than can be established by methods described in **6.3.3.1** and **6.3.3.2**.

Because the detection elements are so sensitive, the level of leakage rate that is considered significant should be determined by experiment, calculation or prior experience and the techniques should apply only after an air test has been done to eliminate major leaks which would contaminate the air surrounding or inside the vessel and prevent small leaks being detected. The tests are best done by introducing air containing the detection agent into the space between shell and lining and examining the inner surface of the vessel for leaks. Greater sensitivity can be obtained by pressurizing the vessel and testing at vent holes in the shell, as higher pressures can be used, but this method does not allow precise location of individual leaks.

The following four basic methods are available, differing in the nature of the impurity and method of detection. In each case a sample of air from the region under test is drawn through the sensing element.

a) The detection agent is a halogen or halogen compound, such as dichlorodifluoromethane, and the sensing element depends on the increase in positive ion formation which occurs at a heated platinum surface when the halogen content of the surrounding air increases.

b) The detection agent is helium gas and the sensing element a mass spectrometer.

c) The detection agent is a radioactive isotope and the sensing element is a scintillation counter or other appropriate device.

d) The detection agent is hydrogen, helium or argon, and the sensing element depends on changes in thermal conductivity of air caused by the presence of the second gas.

Suitable precautions against the hazards introduced by the presence of the active agents should be taken.

6.3.4 *Testing of Vessels Subject to Arduous Conditions* — Additional tests for vessels which are to be operated under vacuum conditions or subject to thermal and pressure recycling should be considered.

6.4 Maintenance and Repair

6.4.1 Any lined vessel should be placed on a schedule for routine inspection for possible failure of the lining, which may be caused by:

a) corrosion, either general or localized;

b) erosion by movement of a product in the vicinity of branches;

c) cracks;

d) bulging of the lining due to:

   1) moisture trapped behind the lining during fabrication;

   2) expansion of gas, forced behind the lining through a pinhole under high pressure, when the high pressure is released; and

   3) collapse of a loose lining due to inadvertent exposure to vacuum conditions.

6.4.2 Both loose and bonded linings can be repaired, provided they have not suffered general corrosion.

6.4.2.1 The affected area in a silver bonded lining is cut away from the vessel and the edges of the holes chiselled trim. A new piece of silver is shaped to fit exactly into the hole and soldered into the place. The hairline joint crack can be covered by electroplating silver, 0·25 mm thick, over an area up to 12 mm on either side of the boundary.

6.4.2.2 Loose linings which have collapsed or have failed for other reasons can be repaired by removing them from the vessel, cutting out the affected area, and welding a new piece of metal in its place.

6.4.3 If tell-tale holes or holes to prevent build-up of gas pressures have been incorporated in the shell it is important that the holes be kept open and that operating personnel be instructed to report any evidence of a leak immediately.

APPENDIX A

(*Clause* 0.6.2)

EXCHANGE OF INFORMATION

A-1. Early consultation and exchange of information should take place between the lining contractor and all parties concerned in the design, manufacture, erection and use of the vessels and equipment to be lined. Complete and accurate scale drawing should be made available to all parties concerned.

The consultations should cover the following:

a) Construction of equipment or vessel to be lined, including location of welds, design of branches and fittings, joints and internal supports for any loose equipment to be fitted later;

b) Nature and concentration of media for which the vessel or equipment is to be used;

c) Operating temperature and pressure ranges;

d) Whether vessel will be subjected to vacuum;

e) Other factors influencing stresses on lining, for example, expansion, contraction, vibration, erosion;

f) Velocity of contents and any abrasive characteristics to be met, especially at points of their entry to the vessel;

g) Means of access for lining materials and installation crew and equipment, lifting facilities, etc;

h) Where existing vessel has been in service on site, details of site conditions that may affect this work being carried out *in situ*;

j) Safety measures on site;

k) Existing surface finish of the vessel to be lined, that is, pitting or thinning due to corrosion, inclusion of traces of product, etc;

m) Inspection and testing of the lining and vessel, including welder's qualification tests;

n) Whether the vessel is to be internally or externally heated;

p) Media other than working media which will be used, for example, steam or chemical agent for cleaning; and

q) Start up and shut down conditions.

(*Continued from page* 2)

Process Vessels Subcommittee, EDC 57 : 2

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INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Conversion*
Force	newton	N	1 N = 1 kg.1 m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

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